

Medical and Biological Factors of Child Speech Development

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Abstract The article examines key medical and biological factors that influence the formation and development of speech in children. The role of hereditary factors, the state of intrauterine development, maternal health, somatic and neurological diseases at an early age are analyzed. The importance of physiological maturity of the central nervous system, auditory and articulatory apparatus for the full acquisition of speech is emphasized. Attention is also paid to the prevention of speech development disorders.

Keywords Speech, Children, Medical and biological factors, Nervous system, Hearing, Articulation

1. Introduction

The formation of speech is a complex process that relies on the maturity and coordinated activity of numerous bodily systems. It is closely linked to the development of the central nervous system, the auditory and articulatory organs, as well as the condition of the respiratory and cardiovascular systems. The rate and quality of speech function development can be significantly influenced by various medical and biological factors that affect prenatal development and the early years of life.

Genetic predisposition plays an important role in the formation of speech functions. Mutations in genes responsible for neuronal migration, the formation of auditory analyzers, and the brain regions involved in speech processing can lead to specific speech developmental disorders or congenital defects such as dysarthria. Family history often reveals recurrent cases of delayed speech development among close relatives.

Children begin to speak at different ages: one child may speak fluently while another struggles to pronounce even a few words. Research shows that the number of words spoken by a child under three years of age depends not only on parental interaction but also on genetic factors [9]. In fact, it has long been known that genes influence the ability to learn speech. Recently, a specific gene associated with this process has been identified the ROBO2 gene. Children possessing one variant of this gene tend to have a larger vocabulary compared to those with another variant. Interestingly, this

gene is located on the third chromosome, near a region associated with dyslexia a reading disorder characterized by difficulties in learning to read despite preserved intellectual abilities. Some children fail to learn to read not because of poor teaching but due to genetic factors that “do not allow” them to do so. For instance, genetic traits may impair a child’s ability to coordinate eye movements along lines of text or disrupt phonemic hearing. Such children require specialized educational programs for reading instruction.

However, the study under discussion examines healthy children. This aspect is crucial for understanding how genes ensure normal development and what causes its disruption. To achieve this, geneticists identify parts of the genome associated with human-specific traits and then analyze the content and functions of the corresponding genes. A similar case involves another gene essential for speech FOXP2. Mutations in this gene were discovered in a family whose members were unable to master grammar. This discovery attracted great attention, as the ability to speak is one of the most distinctive human features separating humans from other animals. The FOXP2 gene was thoroughly studied and found to be active during embryonic development in the brain regions related to speech. Moreover, it was revealed that FOXP2 in humans has evolved in a unique way compared to that in our closest relatives apes and other animals although it also performs “verbal” functions in them. For example, in songbirds, this gene influences song learning [11].

During pregnancy, the mother’s health plays a direct role in the formation of the child’s central nervous system. Conditions such as toxicosis, infections (cytomegalovirus, toxoplasmosis, rubella), chronic diseases, stress, as well as fetal hypoxia and birth trauma can significantly affect this process. These factors may delay the maturation of cortical speech centers and their functional connections.

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2. Research Objective

The aim of this study is to identify the physiological factors influencing the development of speech disorders (such as dyslalia and alalia) in preschool children. Additionally, the study seeks to evaluate the functional characteristics of the nervous, auditory, and articulatory systems involved in speech formation.

3. Literature Review

The study of prenatal and perinatal influences on a child's speech development is one of the key directions in modern pediatrics, neurology, and psycholinguistics. The complex process of speech formation begins long before birth and continues to develop actively during the first years of life, responding sensitively to various internal and external factors.

Intrauterine development creates the fundamental basis for subsequent speech development, forming the neural networks and brain structures responsible for speech perception and production. The main factors influencing this period include:

Insufficient intake of essential nutrients such as folic acid, iodine, iron, choline, and omega-3 fatty acids necessary for neurogenesis and myelination may delay the maturation of the nervous system [4]. Chronic hypoxia or placental insufficiency leading to fetal growth restriction reduces the supply of oxygen and nutrients to the fetal brain, which can result in diffuse or focal lesions affecting cognitive and speech functions.

Infectious processes acquired during childbirth or in the first days of life (such as sepsis or meningitis) can cause inflammatory changes in brain tissue, leading to irreversible neuronal damage and disruption of neuronal connections, which are reflected in cognitive and speech impairments [5].

Fully developed auditory organs that ensure adequate afferentation are crucial for normal speech development. Even minor hearing impairments can reduce the quality of phonemic perception and lead to pronunciation defects. The articulatory apparatus must also be anatomically and physiologically mature, with well-developed fine motor control of the tongue, lips, and soft palate.

The maturity of the auditory system allows a child to adequately understand adult speech and form their own expressive speech. Immaturity of this system may manifest as monotonous speech or incorrect stress patterns, making communication difficult [12].

Auditory control is one of the most important mechanisms of self-correction during speech acquisition. A child listens to their own pronunciation, compares it with adult speech models, and adjusts articulation accordingly. When auditory perception is impaired, this feedback mechanism is disrupted or absent altogether, resulting in persistent pronunciation errors even in the absence of primary defects in the articulatory apparatus.

The production of diverse speech sounds requires the precise, differentiated, and coordinated work of all components of the articulatory system [3]. Immaturity of the nervous system or specific developmental features may manifest as insufficient strength, range, or accuracy in tongue, lip, or soft palate movements. This can cause difficulty reproducing complex articulation patterns necessary for certain sounds (e.g., sibilants, fricatives, or sonorants).

During the maturation of the articulatory apparatus and the acquisition of active speech practice, kinesthetic (muscle-joint) control develops, allowing the child to sense the position and movement of their speech organs. This enables fine self-regulation of articulation and facilitates the automatization of pronunciation skills [14]. Disturbances in kinesthetic sensation can lead to persistent pronunciation errors that are difficult to correct.

Somatic health that is, the overall physical condition of the body indirectly but significantly affects speech development through several mechanisms:

Children with weakened immunity who frequently suffer from respiratory or other illnesses spend much of their physiological resources combating disease and recovery.

Frequent illnesses may cause temporary or chronic hearing loss (e.g., due to otitis), which complicates adequate speech perception and phonemic hearing formation. Moreover, prolonged hospitalization or isolation from peers and reduced speech interaction can slow the development of communication skills.

Deficiency of micronutrients essential for normal nervous system functioning—such as iodine, iron, B-group vitamins, and omega-3 fatty acids can negatively impact myelination, neurogenesis, and synaptogenesis [6]. This may slow the maturation of brain speech zones, leading to delayed or atypical speech development.

Speech is supported by a complex network of interconnected brain areas, including Broca's area (motor speech center), Wernicke's area (sensory speech center), auditory cortex, associative zones, subcortical structures (basal ganglia, cerebellum), and connecting pathways [10].

Speech development is closely interrelated with the development of other cognitive functions such as memory, attention, thinking, and perception. Neurological disorders affecting these functions inevitably manifest in speech as well [1]. For example, difficulty maintaining attention may interfere with the comprehension of long phrases, while impaired logical thinking may hinder the construction of coherent utterances.

Proper functioning of the articulatory apparatus directly depends on adequate innervation and muscle tone [7]. Neurological conditions accompanied by abnormalities in muscle tone (hypertonia, hypotonia, dystonia) or paresis/paralysis of articulatory muscles (as seen in cerebral palsy) can cause significant speech sound disorders, resulting in slurred, indistinct, slowed, or even absent speech.

Adequate medical supervision during pregnancy allows early identification and correction of potential risks such as threatened miscarriage, placental insufficiency, or fetoplacental

dysfunction, which is crucial in preventing fetal hypoxia and its effects on the developing nervous system [15].

Qualified obstetric care aimed at minimizing birth trauma and neonatal hypoxia is one of the key factors in preventing perinatal CNS injuries that often underlie speech disorders.

Fine motor activities (such as finger games, modeling, or drawing) are closely linked to the development of the brain's speech zones, as the cortical representation of the hand is located near speech areas [8]. Stimulation of gross motor activity also promotes the overall maturation of the nervous system and coordination of movements, indirectly influencing articulatory motor control.

Regular hearing screening (newborn audiological screening and scheduled hearing tests) makes it possible to identify hearing impairments early one of the primary causes of delayed speech development [13]. Timely use of hearing aids or cochlear implantation is crucial for developing speech in children with hearing loss.

4. Research Methodology

To empirically verify the theoretical assumptions regarding the significance of medical and biological factors in the development of speech disorders in children, an applied study was conducted in the form of a questionnaire survey among mothers of preschool children diagnosed with speech disorders.

The aim of the study was to determine the frequency and importance of intrauterine, perinatal, and hereditary-genetic factors that may contribute to atypical speech development in children.

The study involved 58 mothers of children aged three to six years who were under the supervision of a speech therapist, pediatric neurologist, or neuropsychiatrist. As a research tool, a structured questionnaire containing closed and semi-structured questions was used. The questions were grouped into thematic blocks, including:

- Pregnancy history (infectious, somatic, and psycho-emotional factors);
- Characteristics of labor and the perinatal period;
- Information about the child's early development;
- Family history (presence of speech or neurological disorders among close relatives).

5. Analysis and Results

Risk factors associated with complicated pregnancies were identified in 63% of mothers, including:

1. Viral infections (including the TORCH complex) - 21%;
2. Toxicosis accompanied by nutritional disorders - 16%;
3. Prolonged chronic stress - 14%;
4. Medication exposure (self-treatment or use of drugs without medical consultation) - 12%.

Perinatal complications such as hypoxia, asphyxia, or operative delivery were recorded in 38% of respondents.

A severe family history of speech development delay, dyslexia, dysarthria, or other speech disorders was found in 28% of cases.

Approximately 17% of questionnaires reflected a combination of both prenatal pathologies and hereditary factors, indicating a multifactorial etiology of speech disorders in these children.

6. Discussion

The survey results made it possible to identify the most significant biological and hereditary risk factors. The findings confirm the importance of early medical, psychological, and pedagogical support for children belonging to risk groups. They also highlight the need for counseling for pregnant women and their families to minimize potential hereditary risks of speech development disorders.

7. Conclusions

A child's speech development is determined by a complex interaction of medical and biological factors ranging from genetic predisposition to somatic and neurological health in early childhood. A comprehensive approach that includes prevention, early diagnosis, and timely professional intervention can significantly reduce the risk of speech disorders and promote the harmonious development of communication skills.

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